Physical and Optical Structures in the Upper Ocean of the East (Japan) Sea (WHOI component)

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LONG-TERM GOALS

This study fits within our broader scientific efforts to understand:

- Physical and biological responses of the upper ocean to atmospheric forcing and how these penetrate to the interior.
- The dynamics and biological influences of instabilities, secondary circulations and vertical motions associated with upper ocean fronts.
- Physical and bio-optical transitions between coastal and central basin waters.

OBJECTIVES

We seek to understand the processes that control physical and bio-optical variability in the upper ocean of the East/Japan Sea. Specifically, we are interested in:

- The upper ocean response to strong wintertime forcing (Siberian cold air outbreaks) at the subpolar front.

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14. ABSTRACT

We seek to understand the processes that control physical and bio-optical variability in the upper ocean of the East/Japan Sea. Specifically, we are interested in: (1) the upper ocean response to strong wintertime forcing (Siberian cold air outbreaks) at the subpolar front; (2) the resulting formation, subduction, and spreading of intermediate waters; (3) the dynamics of the subpolar front; and (4) contrasting seasonal and coastal/central basin bio-optical variability. Highly resolved, three-dimensional upper ocean measurements provide a unique picture of the integrated effects of wintertime water mass formation in response to strong atmospheric forcing and of frontal eddy properties. Simultaneous measurements of bio-optical properties contrasts conditions on either side of the front and permit us to study the role of dynamics in controlling bio-optical variability. Both at the subpolar front and off the Korean coast, SeaSoar surveys provide bio-optical measurements of unprecedented synopticity and horizontal resolution

15. SUBJECT TERMS

Japan (East) Sea, subpolar front, cold air outbreak

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- The resulting formation, subduction, and spreading of intermediate waters.
- The dynamics of the subpolar front.
- Contrasting seasonal and coastal/central basin bio-optical variability.

APPROACH

Two cruises, the first in May 1999 followed by a second in January 2000, sampled upper ocean and atmospheric boundary layer (Drs. C. Dorman, SIO, R. Beardsley and J. Edson, WHOI) variability in the Japan/East Sea. The spring cruise focused on frontal dynamics, characterizing bio-optical variability associated with the spring phytoplankton bloom and documenting the location, range and properties of water masses formed at the subpolar front during the preceding winter. The wintertime cruise documented the upper ocean response to a series of cold air outbreaks with particular attention to processes associated with water mass formation and subduction at the subpolar front. Both cruises employed a towed, undulating profiler (SeaSoar) to make highly-resolved observations of the upper ocean. We used real-time remotely sensed sea surface temperature and ocean color images (R. Arnone and R. Gould, NRL) to determine the location of the subpolar front and to select intensive survey locations. Real-time access to remotely sensed imagery allowed us to modify our sampling in response to changes in the front. Repeated intensive grid surveys provided approximately synoptic, three-dimensional coverage while a sequence of longer sections documented oceanic and atmospheric boundary layer variability away from the front. In addition to the suite of physical and bio-optical sensors carried by SeaSoar, we employed a shipboard Acoustic Doppler Current Profiler (ADCP) and GPS navigation to measure upper ocean currents. Sampling included a limited number of hydrographic stations and optical profiles off the Korean coast and across the subpolar front. Professor S. Yang (Kwangju University) was responsible for additional biological and bio-optical sampling (e.g. nutrient analysis, pigments). Dr. M. Suk (KORDI) and colleagues provided additional support.

WORK COMPLETED

We have successfully completed both SeaSoar cruises, the both of which were documented in annual reports, and will not be discussed here in detail. Sampling was concentrated on the persistent, meandering subpolar front that is consistently found running east-west across the Japan (East) Sea (figure 1). Sampling was typically informed by remotely sensed information and was always carried out with an eye towards collaboration with other program investigators. Typically SeaSoar observations include highly resolved (in space) measurements of temperature, salinity, density, light transmission and chlorophyll flourescence.

Both cruise data sets have now been completed processed and quality-controlled. Web sites now document the data sets themselves, and a CD is available on request. Analysis (led by C. Lee at the University of Washington) is well along the way, and a major manuscript is in preparation.

This project is completely integrated with the Lee and Jones efforts. Although this component's funding has run out, Lee and Jones are still actively completing their research publications.

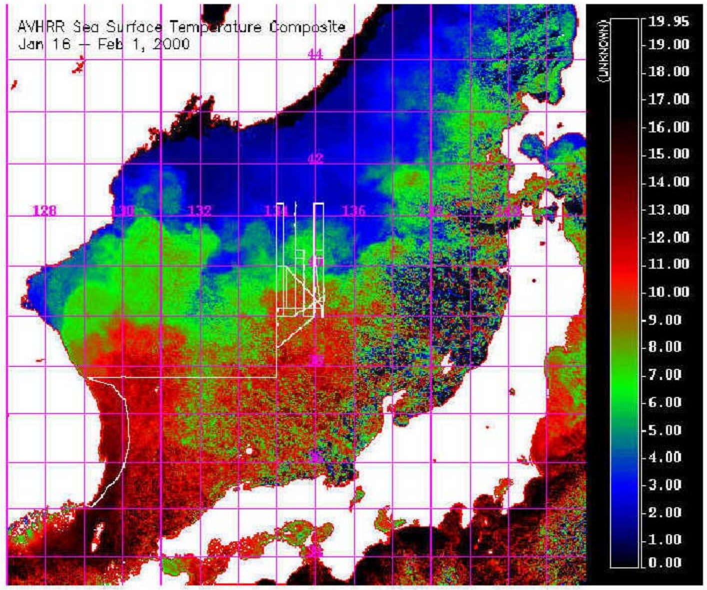

Figure 1. *Composite AVHRR sea surface temperature image from 16 Jan - 1 Feb 2000 (R. Arnone, R. Gould and C. Chan). The white line marks the SeaSoar survey track.*

RESULTS

The wintertime cruise spanned three distinctive Siberian cold air outbreaks, which brought strong winds and cold, dry air to our sampling region near the subpolar front. Surface waters north of the front were warmer than anticipated from previous observations, though the warmest waters just north of the front were associated with an eddy (Fig. 2). Following the passage of the first cold air outbreak, the front sharpened and surface temperatures cooled by nearly 2 °C , presumably through some combination of net surface cooling, convective overturning and horizontal advection. An anticyclonic eddy occupied the region just north of the subpolar front, characterized by warm (6 °C), fresh (< 33.9) waters extending below 250 m and clockwise surface flows of nearly 0.5 m/s (Fig. 2). Mixed layer temperatures cool to 2 °C north of the eddy, with only weak stratification in the underlying pycnocline. South of the front, shallower (50 m), warmer (> 10 °C) mixed layers rest on top of a strongly stratified pycnocline (Fig. 2). Of particular interest are the weakly stratified, negative salinity anomaly watermasses found beneath the mixed layer base south of the front. These features have horizontal scales of O(10 km), vertical scales of O(10 m) and appear between the 26.5 kg/m^3 and 27.0 kg/m^3 isopycnals in nearly all of the cross-front sections. Selected sections also exhibit elevated bio-optical variability associated with negative salinity anomaly regions closest to the frontal interface. The density range, weak stratification and observed salinities within these features are consistent with the characteristics expected of northern waters that have been subducted along the front and injected beneath the southern-side mixed layer (Lee et al., in preparation). Along-front horizontal advection also probably plays a strong role. Further analysis has detected clear signs of symmetric instability (L.N. Thomas, University of Washington).

Collaborative use of the SeaSoar data set helped detect and define the properties of subthermocline eddies, that appear to be common in this marginal sea (Gordon et al., 200x).

RELATED PROJECTS

Our efforts are part of an intensive, multi-investigator study of the Japan/East Sea. We intend to collaborate closely, both in the measurement and analysis phases, with other Japan/East Sea projects. In particular, we anticipate cooperation with the following components:

Satellite Characterization of Bio-Optical and Thermal Variability in the Japan/East Sea, B. Arnone, (NRL).

Atmospheric Forcing and its Spatial Variability over the Japan/East Sea, R. Beardsley, A. Rogerson (WHOI) and C. Dorman (SIO).

Optical Properties as Tracers of Water Mass Structure and Circulation, G. Mitchell, D. Stramski and P. Flatau (SIO).

Glider Surveys of the Japan/East Sea Circulation, C. Eriksen (University of Washington).

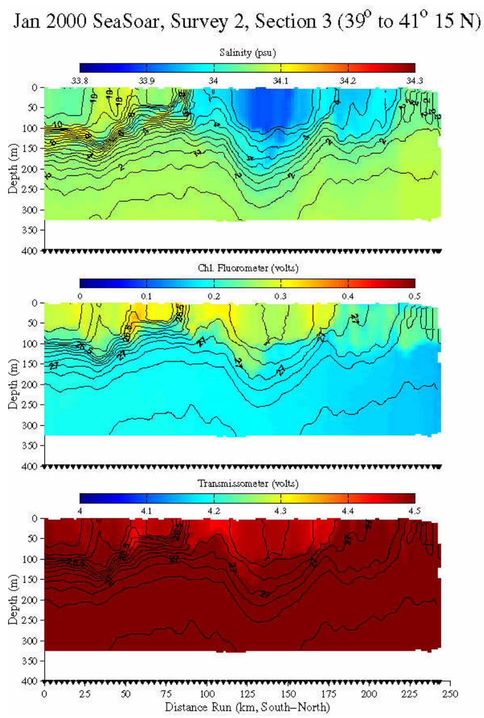

Figure 2. *Wintertime SeaSoar section (third section counting west to east across the survey pattern) across the subpolar front, occupied immediately following the first cold air outbreak. Temperature is contoured in the top panel, while potential density is contoured in the bottom two frames.*

Modeling Support for CREAMS II: Oceanic and Atmospheric Mesoscale Circulation and Marine Ecosystem Simulations for the Japan/East Sea, C. Mooers and S. Chen (University of Miami).

Wind Forcing of Currents in the Japan/East Sea, P. Niiler (S.I.O.), D. Lee (Pusan National University) and S. Hahn (National Fisheries Research and Development Institute).

Observations of Upper Ocean Hydrography and Currents in the Japan/East Sea using PALACE Floats, S. Riser (University of Washington).

Hydrographic Measurements in Support of Japan/East Sea Circulation, L. Talley (SIO).

Shallow and Deep Current Variability in the Southwestern Japan/East Sea, R. Watts and M. Wimbush (University of Rhode Island).

IMPACT/APPLICATION

Highly resolved, three-dimensional upper ocean measurements provide a unique picture of the integrated effects of wintertime water mass formation in response to strong atmospheric forcing and of frontal eddy properties. Simultaneous measurements of bio-optical properties contrasts conditions on either side of the front and permit us to study the role of dynamics in controlling bio-optical variability. Both at the subpolar front and off the Korean coast, SeaSoar surveys provide bio-optical measurements of unprecedented synopticity and horizontal resolution.

TRANSITIONS

None.

PUBLICATIONS

Fox, D.N., W.J. Teague, C.N. Barron, M.R. Carnes, and C.M. Lee, 2002: The Modular Ocean Data Assimilation System (MODAS), submitted to *J. Atm. Ocean. Tech***., 19**, 240-252.

Gordon, A. L., C. F. Giulivi, C. M. Lee, A. Bower, H. Hunt-Furey and L. Talley, 2002: Japan/East Sea intra-thermocline eddies, *J. Phys. Oceanogr*., **32**, 1960-1874.

Lee, C. M., C. E. Dorman, R. W. Gould and B. H. Jones 1999: Preliminary Cruise Report: Hahnaro 5-Dynamics, Biology, Optics and Meteorology of the Subpolar Front in the Japan/East Sea. *Technical Memorandum, APL-UW TM 3-99*, Applied Physics Laboratory, University of Washington, 65pp.

Lee, C.N., K.H. Brink and B.H. Jones (in preparation). Physical and optical processes near the subpolar front in the Japan (East) Sea. (Title and authorship tentative).